WINTER AGGREGATION OF *HARMONIA AXYRIDIS* (COLEOPTERA: COCCINELLIDAE) IN A CONCRETE OBSERVATION TOWER[1]

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ABSTRACT: Aggregations of thousands of multicolored Asian lady beetles, *Harmonia axyridis*, have appeared each fall since 1993 in a 20.1 m high concrete observation tower at Mt. Gretna, Lebanon County, Pennsylvania. The tower is located in a clearing on a ridge in otherwise regenerated oak-maple-birch forests in Clarence Schock Memorial Park at Governor Dick (326 m elevation, 40° 14.78' N, 76° 27.35' W). Beetles aggregate in the ceiling/wall corners on four different levels in the tower's internal ladderways. Since the tower is open to the public for recreational purposes, one can visit the tower in late fall and witness these aggregations. During some winters, mortality appears very high, suggesting that the tower lacks adequate insulative properties for optimum survival.

KEY WORDS: *Harmonia axyridis*, Coleoptera, Coccinellidae, winter aggregation, lady beetle, overwintering mortality, fall flight behavior.

Since the multicolored Asian lady beetle, *Harmonia axyridis* (Pallas) was first detected in North America (Louisiana) in 1988 (Chapin & Brou 1991), there has been considerable interest in this beneficial predator of aphids. Although it has had a positive impact against aphid pests [e.g. on pecan in the Southeast (Tedders & Schaefer 1994; De Quattro 1995) and apple orchards in West Virginia (Brown and Miller 1998)], it has also irritated many homeowners when adult beetles begin aggregating in the fall, alighting on and entering homes and other buildings seeking sites for overwintering (see Kidd *et al.* 1995 regarding the human impact). Nalepa *et al.* (1996) investigated aspects of *H. axyridis* biology (sex ratio, dimorphism, phenotype, parasitism) in winter aggregations and later aggregation behavior in response to artificial shelters (suggestive of bee hives) and the utilization of active apiary bee hives as aggregation sites (Nalepa *et al.* 2000). I provide a description of a large observation tower (See web address for illustration), similar to the silo illustrated in De Quattro (1995), located in south central Pennsylvania, that appears to meet criteria for successful *H. axyridis* aggregation, and that is readily accessible to the public.

METHODS

Tower Site. Located in Clarence Schock Memorial Park at Governor Dick, West Cornwall district near Mt. Gretna, Lebanon Co., Pennsylvania, a naturally regenerated forest, is a cylindrical, reinforced steel and concrete observation tower (20.1 m high and 4.6 m in diameter) built on the crest of a ridge (326 m elevation, 40° 14.78' N, 76° 27.35' W) to provide a panoramic view of the surrounding countryside. The tower is reached by a 30-minute walk and is used by recreational hikers who ascend the tower's internal ladderways to reach the observation deck on top for a view from above the surrounding forest canopy.

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The tower sits in a small clearing that was enlarged in 1996 but is otherwise surrounded by forests of hardwoods and a few conifers.

After first observing the tower in spring 1994, I made from one to three annual fall and then some follow-up spring inspections of the tower from 1994 to 2002. During many visits, I photographed the aggregations, collected some or all available beetles for unrelated studies, and on specific visits (Nov. 2000) took a GPS fix using a Model GPS III Plus (Garmin Corp., Olathe, Kansas, USA) and light intensity readings (March 1998) of the external surface and internal ladderways using a Minolta Auto Light Meter IV F, using spherical, flat and mini-receptor (Minolta Co, Ltd, Japan). I measured the relative light intensity in full sun away from the tower, on the outer surface, at the entrance level, and in the four upper levels, both ½ m directly inside of the slit window, and in the actual ceiling corners where the aggregations occurred.

On three consecutive inspections (1995 - 1997), I collected all exposed beetles aggregated on the south ladderway of the tower and isolated samples from each of the four levels (Figure 1). Beetles were brushed into a square plastic funnel, transferred to paper cartons, and returned to the laboratory. Individual containers from each level were weighed, weight of beetles alone was calculated, and beetles were then counted.

On many visits the progress of the aggregation formation was noted, photographed, appreciated, and then left for future visitors or visits.

RESULTS AND DISCUSSION

The tower was first found to contain aggregations of *H. axyridis* in the fall of 1993. A. G. "Al" Wheeler, Jr. (formerly at Penn. Dept. Agric., Harrisburg, now Clemson Univ.) first learned of the beetle aggregations from a Harrisburg coworker and visited the site that same season. In mid-April 1994, Al and I visited the tower to find large quantities of dead beetles at all aggregation sites. We found only a few live beetles crawling about the outer tower surface. We concluded that either beetle survival had been very low or that all other survivors had already dispersed into nearby forests. We concluded that the intervening winter had killed large proportions of aggregated beetles. The tower was acceptable for aggregation but appeared to provide insufficient protection (e.g. low temperatures, desiccation) for optimal overwintering survival.

Based on the 1995 - 1997 beetle collections, mean numbers (based on 15,016 beetles collected), showed a slight but statistically insignificant decrease of beetles with tower height (Table 1). Thus beetles flew onto the tower irrespective of height and entered the slit-like windows (10 x 30 cm) at all levels equally and tended to avoid the tower entrance. This suggests that beetle flights occur uniformly at levels up to ca. 20 m in the vicinity of the tower. Mean calculated weight of an individual beetle in 1997 was 33.25 mg (n=5,762). Captured beetles were used for various research purposes, including our attempt to identify possible aggregation pheromones and potentially useful repellants (in collaboration with Jeffrey Aldrich, USDA, ARS, Beltsville, MD).

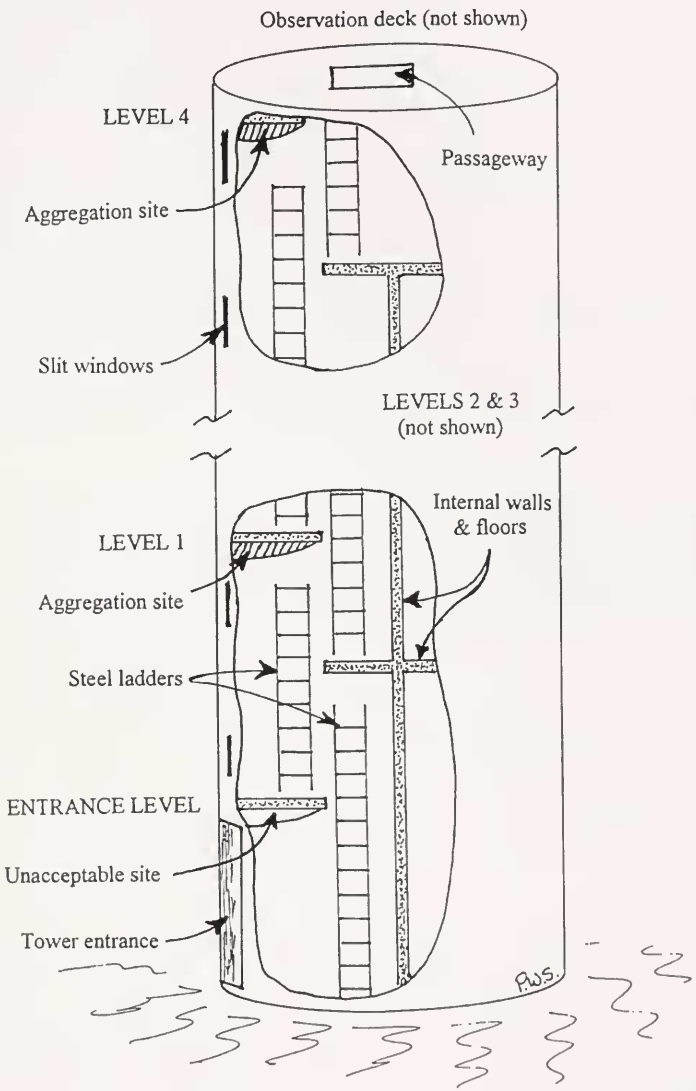

Figure 1: Observation tower at Clarence Schock Memorial Park at Governor Dick, Mt. Gretna, Pennsylvania, where *Harmonia axyridis* have aggregated annually since first discovery in 1993. The concrete tower is 20.1 m (66 ft) high and 4.47 m (15 ft) in diameter with internal beetle aggregation sites consisting primarily of 2.9 m of ceiling/wall interface at each of four levels. The west tower entrance (shown) faces 275° from magnetic north. This entrance level provides a similar area that is generally rejected by beetles. A corresponding enclosed ladderway, window slits, and entrance on the opposite or east side (not shown) is used by beetles to a lesser extent than the west side because of the orientation of the sun on mid- to late-afternoon sunny days in October and November when the beetles take flight.

Data on light intensity, particularly when considering that no or very few beetles aggregated at the naturally illuminated tower entrance, point to the importance of diminished light. At 3:30 p.m. on March 26, 1998, the full outside sunlight measurement was 36,000 lux (hereafter all measurements are converted to a percentage of this figure); reflectance on the outside concrete surface was 36%; while ½ m inside the entrance the light intensity was down to 4.2% and at the possible aggregation niche it was 2.0%. At upper levels 1 thru 3 the mean light intensity ½ m from the window slits was much lower (0.13%) and at the ceiling/wall interface (beetle aggregation sites) light intensity was only 28 lux or 0.08%. In contrast to these acceptable aggregation sites (Levels 1-4); the entrance level was devoid of beetles, suggesting that the difference between 740 lux and 28 lux made the difference, since the physical structure was similar with the exception of the brighter door-sized entrance (Figure 1). Severely diminished light intensity appears to act as a behavioral arrestant, and this may be one important factor in successful beetle aggregation.

Table 1. Mean *Harmonia axyridis* collected in the southwest side of the observation tower in Clarence Schock Memorial Park at Governor Dick, Mt. Gretna, Pennsylvania, during the winters of 1996 through 1998 and survival of beetles at upper and lower two levels pooled during November-February 2001. Levels refer to potential beetle aggregation sites, i.e. 2.9 m of ceiling/wall interface (See Figure 1).

					2001 Survival:	
Level	Height (m)	3 yr. total	Mean	SD	Total No.	% Alive
4	19.8	3,017	1,005.7a	301.3	796	57.4
3	15.8	3,016	1,005.3a	154.1		
2	11.7	4,056	1,352.1a	180.5	1,176	62.6
1	7.3	4,927	1,642.3a	467.6		
Entrance	2.2	0	0b	0		
Total/Mean		15,016	5,005.3	769.3	1,972	60.5

1. Based on the Student-Newman-Keuls test, means with the same letter are not significantly different (P= < 0.05).

In the fall of 1998, I discovered that all internal surfaces of the tower had been painted white. White paint had also been applied to the outside of the tower up to the 3.4 m level. This seemed to somewhat alter the general behavior of beetles in comparison to the years before painting, perhaps through differential surface texture, color, or contact stimuli. On November 1, 2000, I found many beetles slowly walking on concrete surfaces and only a few had aggregated in corners.

Some small clusters were present on the external surface of the tower. Another inspection 22 days later showed beetles rather loosely organized in clusters. Some of the small clusters remained on the external surface positioned at the concrete/white paint interface on the tower's southwest exposure. I also counted 231 *H. axyridis* positioned on the entrance level, just inside the entrance door (south side only) and I estimated at least a 5-fold increase on Level 1. I assume that colder temperatures soon thereafter forced all beetles into the darker, internal recesses of the tower ladderways but no visits confirmed this movement.

Based on collective observations at this tower and experiences at other sites (i.e. two old silos in Middletown, Delaware, and the Ironmasters House, Pine Grove Furnace State Park, near Gettysburg, Penn., on October 18, 1994) I propose the following behavioral sequence: *H. axyridis* beetles annually fly on warm, still, fall afternoons and then alight on the tower surface, crawl over the surface, and enter the slit windows to the internal ladderway 81 cm (32 inches) wide, and in diminished light aggregate at the ceiling-wall interface (Figure 1). At first the beetles cluster loosely, with many stragglers, and as colder days occur beetles progressively cluster together in tighter aggregations. In addition, some beetles packed tightly into the hollow ends of the steel ladder rungs, and in drain holes (from the floor above), and others accumulated on the tops of steel ladders and upright wooden guards opposite each ladder. In all locations, beetles remained nearly motionless or moved very sluggishly. Beetle survival was then dependent on the cumulative exposure to winds and sub-freezing temperatures.

Winter survival of the beetles appears to be very unpredictable. During the winter of 1994, the majority of beetles in these aggregations apparently died in *situ*. Probably the steel and concrete structure of the observation tower provided too little thermal protection for overwintering survival. Since I removed most beetles yearly beginning in the fall of 1995, I cannot comment further on survival in those winters, with the exception of the winter of 1997-1998 (an unusually mild winter). During that winter, when beetles had not been removed the previous fall, there was no evidence of mass mortality in March 1998. On February 15, 2001, after an unseasonably cold December, I collected beetles and determined that overall survival was 60.5% (Table 1). The following November (2002), beetles had aggregated as usual but the overall numbers diminished to approximately 1/10 that of the winters of 1995 and 1996 based on comparative photographs.

The observation tower continues to attract *H. axyridis*, but it is clear that it sometimes fails to provide sufficient insulation to maximize survival during unusually cold winters. One can only imagine that in the cracks and crevices of a natural rock outcropping (where I have observed naturally occurring aggregations in Hokkaido, Japan), aggregated beetles might experience warmer subsurface temperatures (considerably more constant and never so severely cold as ambient air temperatures), higher moisture levels, and perhaps also the insulating advantage of snow cover. Optimum winter survival of *H. axyridis* may occur

under these conditions. In conclusion, the Mt. Gretna observation tower has become a reliable site to observe and collect *H. axyridis* in late fall even though the survival of all aggregated beetles is very much dependent on the collective severity of ambient winter weather. The tower also makes a very convenient site for the general public to hike up the trails in late fall, enjoy the scenic view, and witness the annual aggregation of these invasive, yet remarkable lady beetles.

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